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THE DAMAGES TO RECREATIONAL ACTIVITIES FROM PCB's IN THE NEW BEDFORD HARBOR

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Prepared for:

National Oceanic and Atmospheric Administration
Ocean Assessment Division
11400 Rockville Pike
Rockville, Maryland 20852

Prepared by:

Kenneth E. McConnell
University of Maryland

and

Industrial Economics, Incorporated
2067 Massachusetts Avenue
Cambridge, Massachusetts 02140

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K. E. McConnell
University of Maryland

INTRODUCTION

PCBs have lowered the use value of recreational resources in the New Bedford Harbor area. In the case of beach use, the economic loss is measured as the present value of the reduction in willingness-to-pay for access to beaches which recreationists view as less desirable. For recreational fishing, the damages are measured as the increase in costs incurred by recreational fishermen who want to fish in the general area but must travel farther to avoid contaminated areas. These increased travel costs are a measure of the recreational fisherman's minimum willingness-to-pay for fishing in areas uncontaminated by PCBs.

This report estimates the present value of damages to beach use to be $7.51 million and the damages to recreational angling to be $2.02 million. Total damages are estimated to be $9.53 million. Part I of the report presents the evidence for beach use and Part II for recreational angling. Part III gives the present value, in 1986, of the joint damages to fishing and beach use.

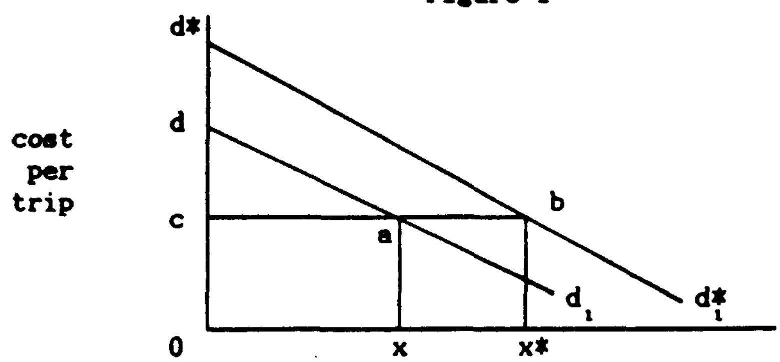
I. THE DAMAGES TO BEACH USE

A. Framework

The contamination of New Bedford Harbor with PCB's has resulted in elevated levels of PCB's near beaches in the greater New Bedford area. This analysis is an approach to estimating the damages caused by the reduction in environmental quality at various beaches.

In the simplest case, when there is only one beach, a reduction in the quality of the beach influences the demand for the beach. A change in the demand for the beach implies a change in the user's willingness to pay for access to the beach. This analysis is told graphically in Figure 1.

Figure 1



Let $d^*d_1^*$ be the demand curve for going to the beach in the absence of PCB contamination. The consumer's net willingness to pay for access to the beach can be approximated by the area d*bc, the area under the demand curve and above the price. Now the presence of PCB's reduces the demand for visits to the beach to dd_1. The new willingness to pay for access is dac. The reduction in willingness to pay for access to the beach is dabd*, the damage to an individual beach goer from contamination by PCB's.

When several beaches are contaminated, this straightforward analysis holds as long as individuals use only one beach, that is the same beach, both before and after the quality change. Then we can compute aggregate benefits for quality changes at all beaches by adding areas under individual demand curves.

However, when an individual visits more than one beach, the analysis becomes more complicated. The complication is caused by the fact that the level of contamination at one beach influences the demand for other beaches. Consider the two beach case, the number of beaches to be analyzed for New Bedford. The demand for beach 1 depends not only on the environmental quality at beach 1, but the quality at beach 2; similarly for beach 2. Then the conceptually correct measure of value for a change in the contamination at both sites should be calculated as follows (see the appendix for a derivation of this result):

> the change in the area under the demand curve at beach 1 induced by the quality change at beach 1, assuming quality at beach 2 at its initial level
>
> +
>
> the change in the area under the demand curve at beach 2 induced by the quality change at beach 2, assuming quality at beach 1 at its new level.

This definition of damages encompasses the sequencing of quality changes. It requires the evaluation of beach 1 at the original environmental quality for beach 2 and the evaluation of beach 2 at the subsequent quality at beach 1. The same kind of sequencing occurs in the case of multiple price changes. (See, for example, Just, Hueth and Schmitz.) As is shown in the first part of the appendix, the same reasoning occurs when the recreationist chooses among many beaches, only two of which are polluted.

There are two problems which arise in the practice of this method. The problem that arises in any situation is that the demand curves we observe are Marshallian or income-constant demand curves, not the Hicksian or utility-constant demand curves used in the development of the approach. The second problem which arises as an artifact of the New Bedford study is that we only observe (or estimate) each demand curve at the initial and subsequent quality levels at all beaches. That is, we miss the sequencing. Both of these problems are explained in the appendix.

The standard approaches for estimating the recreational benefits for environmental quality typically rely on variations in quality across sites. (See Smith and Desvousges, and Kling, Bockstael, and Strand, for example.) In the case of PCB's in New Bedford Harbor, this approach is not feasible. Because PCB's are not perceptible to water recreationists, people tend to use other information to learn that sediments in the vicinity of New Bedford beaches are polluted with PCB's.

The approach taken in this report differs from standard approaches due to the absence of observable changes in behavior induced by changes in PCB levels at different beaches. The basic approach is as follows:

A. Estimate the 'with PCB's' demand function for contaminated beaches using survey data for planned beach visits for 1986.
B. Estimate the 'without PCB's' demand function for contaminated beaches using responses to the interviewer's question for 1986.
C. Calculate the costs of PCB's calculating the benefits of beach access under A and under B and subtracting A from B.

While the general approach involves steps A - C, the credibility of the results depends most crucially on the details of the implementation. The first part of the appendix demonstrates that for complete assessment of damages, one need only estimate demand changes for beaches perceived to be polluted, rather than all of the beaches.

B. New Bedford Area Beaches

There are a number of town, state, and local beaches in the New Bedford area. Exhibit 1 presents the approximate location of these beaches. These beaches vary considerably in their physical and aesthetic characteristics. A brief summary of these characteristics is presented in Exhibit 2. This beach information was developed from site visits and discussions with local and state officials. East and West Beaches, the only beaches in the town of New Bedford, are the two most urban beaches in the area, and have nearly identical features. Each beach extends right up to a major road and has either a long jetty or a pier at one end. Both of these beaches are visited primarily by local citizens and summer residents. Two of the three state beaches in the area — Demarest Lloyd in Dartmouth, and Horseneck Beach in Westport — are large, state reservations with numerous facilities, varied natural features, and extensive beaches. Both beaches are used by local, regional, and state visitors. Fort Phoenix, in Fairhaven, is the third state beach in the area. It is smaller and somewhat more developed than the other two state beaches, and is used primarily by local citizens and summer residents.

The town beaches in Fairhaven and Dartmouth are fairly similar to one another. In general, they are relatively undeveloped and primarily attract neighborhood visitors. Some of these local beaches are quite small. The towns of Fairhaven and Dartmouth also have a few informal and local beaches that are also small in size and that have few or no facilities. There are several informal beaches along West Sconticut Neck that have limited public access.

The sediments near several of these beaches have been contaminated with PCB's. Exhibit 3 shows the PCB sediment concentrations measured in the Acushnet River Estuary. The beaches that appear to be affected by concentrations from 2 to 10 ppm PCB's are Fort Phoenix, East Beach, West Beach, Jones Beach, and beaches along West Sconticut Neck (Shell Beach).

In the analysis below, the focus will be on the damages at East, West, and Fort Phoenix beaches. While some households may perceive that other beaches may have been tainted, the analysis will be limited to the three mentioned beaches. The potential for affecting perceptions at other beaches implies that the damage assessment completed below may underestimate the true damages incurred.

C. Sources of Data

The empirical work of this report is based upon a telephone survey of households in the New Bedford area. This survey, described in detail below, gathered detailed information about beach going and fishing activities and perceptions of PCBs. It was necessary to design and execute a survey because current sources of data are not adequate for estimating damages for a variety of reasons.

To serve the purpose of recreational damage assessment, a data source must meet at least the following criteria:

1) The source must be site-specific; that is, it must give information about individual behavior at the specific site of concern.

2) The source must give information in sufficient detail to allow researchers to explain how behavior changes in response to costs of access and other important determinants of behavior.
3) The data must have been gathered in a systematic way, from one observation to another and from one time period to another.

If the first criterion is not met then the data cannot be used to infer damages at a specific site, because there is no information about changes in behavior at that site. If the second criterion is not met then there is no basis for inferring damages because it will not be possible to estimate the effects of the costs of access on individual quantity demanded. As we can see from the earlier discussion, damage assessment stems from observing not only how behavior changes in response to environmental quality, but also in response to cost changes.

For beach use and recreational swimming, statistics on attendance are available for some beaches. Ten of the beaches given in Exhibit 1 have some sort of annual attendance data. Thus there are some site-specific data. However, neither the second nor the third criterion is met. The data on attendance cannot be used to determine how people's beach attendance responds to cost increases because data are aggregated over people with different costs in different years. Thus, even if the data were gathered systematically, and were free of obvious errors, they would not lend themselves to the task of damage assessment.

The beach attendance data also fail to meet the third criterion. The data are gathered in an unsystematic way, and they do not support reliable inferences about changes in aggregate attendance from one year to the next. There are two major sources of errors. The first is the variable and incomplete sample period during which data are gathered from year to year. The second is the variation in the sampling method over time and from beach to beach.

Variation in the sample period is evident from examining specific beaches. For instance, statistics are lacking at some beaches for the non-swimming months, while at other beaches statistics are missing for certain weeks during the summer. The three state beaches, Fort Phoenix, Demarest Lloyd, and Horseneck, have statistics for all the summer months from 1973 to 1985, but the latter two beaches are missing attendance figures for some (but not all) of the fall, winter and spring months from 1978 through 1984. In addition, during these non-summer months, attendance data at these three beaches were collected irregularly, usually only during fair weather weekends. Beach attendance data at East and West Beaches were compiled for 1971 through 1985, but were collected only during the summer season. Thus, there are no data available for beach visitation from early September through late June. Further, the number of weeks during the summer when attendance figures were collected is inconsistent from year to year. For instance, in 1984 attendance statistics were compiled during nine summer weeks, while in other years, attendance was collected for either 10, 11, 12, or 13 summer weeks.

Finally, the beach statistics collected for three of the town beaches — Apponagansett, Round Hill, West Island (Fairhaven town beach) — are incomplete because they are based on the number of car stickers sold to the residents each year, rather than on daily counts of cars or individuals. Thus, it is not possible to use these data to estimate total number of visits for the year because there is no information available on how often the sticker-owners visit the beach.

A second major shortcoming of the area beach attendance data is the variation in sample methods used at different beaches to measure attendance. Because of this variation in counting methodology, it is difficult to compare weekly or seasonal attendance figures between the state beaches and the New Bedford beaches. The state beaches compile daily visitation figures by counting the number of entrance tickets sold to cars. Total number of daily visitors are calculated by multiplying the number of tickets sold times the average number of persons per car. This average number of occupants per car is estimated for each beach once every three years, based on data collected during one summer's day. In addition, these state beaches also calculate the number of "non-paying" visitors. These include walk-ins, bicyclists, and vehicles that have purchased yearly seasonal passes. While this method has been used consistently at the state beaches during the past decade, attendance figures are inaccurate for several reasons. First, the average number of passengers per car used to calculate total number of visitors is estimated only once every three years, and is based on only one day in the summer. If this sampling day is not representative of the entire season, or if the average number of visitors changes significantly during the subsequent two years, then total beach attendance figures may be significantly over- or understated. Second, this method understates attendance totals because it does not count individuals who walk into the beach from non-entrance points.

The method used to count visitors is quite different at East and West Beach. At these New Bedford beaches, a city recreation employee (either a lifeguard, maintenance person or water safety instructor) estimates the total number of daily visitors by estimating the number of individuals on the beach and in the water at mid-afternoon. This method may tend to either over- or underestimate attendance figures depending on the accuracy of the employee. Further, beach attendance estimates made at the end of the summer may be more accurate than estimates made earlier in the season because of the increased experience (and thereby increased accuracy) of the employee. In general only two employees at each city beach will estimate attendance during the entire summer season, thereby reducing some of this potential seasonal bias. However, the data for East and West beaches may be inconsistent from year to year because the employees estimating the number of people on the beach have changed from one year to the next during the past decade. Attendance figures at these beaches are also understated because attendance is estimated only once a day, and therefore does not take into consideration beach turnover.

Finally, the sampling methods used at all beaches also understate total attendance figures because they do not include individuals attending these beaches after hours (e.g., in early morning or evening) during the months when statistics are gathered.

Other than the data on beach attendance discussed above, there are no sources of data which could be used to estimate the damages of PCB contamination to beach use. As a consequence a survey of households in the New Bedford area concerning beach use in the area was designed and executed.

D. The Recreational Survey[1]

The data used for inferring damages to beach use and fishing in the New Bedford area are based on a telephone survey conducted by Decision Research Corporation (DRC) during March-April 1986. The instrument for this survey is attached to this report. The survey was conducted in accordance with established standards of the public opinion research industry. Interviewers questioned 545 New Bedford area households concerning their recreational habits, their knowledge of PCB's, and certain socioeconomic characteristics. Additional information concerning distances to various area beaches was derived from knowledge of the census tract where the household resided.

DRC began the telephone survey with a random sample of households with listed telephone numbers in the cities/towns of New Bedford, Fairhaven, and Dartmouth. The sampling procedure was designed to ensure that every household with a listed telephone number in the specified geographic area was equally likely to be included in the random sample. The sample list included name, address, telephone number, and census tract number for each household.

All interviews were conducted by trained and experienced interviewers at the DRC central interviewing facility in Boston. Prior to beginning the administration of the survey instrument, interviewers were thoroughly briefed on the skip patterns of the survey, the proper method of asking each question, and appropriate methods of probing for acceptable answers (e.g., specific numbers rather than qualitative responses). To avoid biasing the responses to survey questions, DRC interviewers are trained to maintain objectivity when asking questions. Furthermore, interviewers, coders, data processors, and supervisors were all unaware of the identity of DRC's client, and the intended use of the data. Thus, the survey personnel were not able to consciously bias the results of the survey to serve the client.

Five hundred forty-five (545) interviews were completed during the time period March 25 through March 31, 1986. Because of a large population of Portuguese-speaking residents in the New Bedford area, all respondents of Portuguese descent were given the option of having the interview conducted in Portuguese. Each survey participant met the following criteria: current resident of New Bedford, Dartmouth or Fairhaven; lived in the New Bedford area for a minimum of one year; at least 18 years of age; and, one of the members of the household who decides which beaches to visit (for questions pertaining to beaches) or where to saltwater fish (for angling questions).

Several precautions were taken to increase the chances that each household included in the sample would actually be contacted, and therefore, that the survey results would be representative of the New Bedford community. Surveys were conducted at various times of the day, evening, and over the weekend (20% weekday; 62% evening; and 18% weekend interviews). All working numbers included in the sample list were attempted three times, with attempts occurring on a different day of the week and during a different time of day (i.e., unsuccessful daytime attempts were called back during the evening on a different day). Interviewers were also instructed to record carefully specific times that respondents requested that they be recontacted, and supervisors closely monitored the callback times to ensure that interviewers placed calls at the specified times.

All completed surveys were checked by supervisors for completeness and accuracy immediately after each interview. All responses were coded and processed "in-house" by DRC. The execution of these tasks by DRC staff under close supervision ensured high levels of reliability and quality control. Data entry (with 100% verification) was conducted by an outside supplier.

B. Empirical Analysis

The costs of the PCB contamination are computed only for East Beach and West Beach in New Bedford and Fort Phoenix Beach in Fairhaven. These are the main public beaches which lie within the areas potentially contaminated by PCB's. In the following, I will use the survey returns to measure the costs of PCB contamination at East Beach, West Beach, and Fort Phoenix.

The analysis proceeds with the estimation of two demand curves for each site: first the current (with PCB's) demand curves and second the "without PCB's" demand curve. The Marshallian demand curves are of the form

$$x_{ij} = \begin{cases} g(z_{ij};\beta_j) + \varepsilon_{ij} & z_{ij}\beta_j + \varepsilon_{ij} > 0 \\ 0 & z_{ij}\beta_j + \varepsilon_{ij} \leq 0 \end{cases}$$

where

i = observation on household;
j = East Beach, West Beach, Fort Phoenix;
x_{ij} are trips by the i^{th} household to the j^{th} beach;
z_{ij} are the demand function arguments, i^{th} household, j^{th} beach;
β_j is the vector of parameters for demand functions to be estimated for the j^{th} beach; and
ε_{ij} is a $N(0,\sigma_j^2)$ random variable.

The vector of coefficients β_j will be estimated for the "with" and "without PCB's" demand curve for each site.

Several problems arise in the estimation of these demand curves. First, for any beach, many people interviewed did not attend. This problem is handled by estimating a Tobit model, which accounts for the piling up of observations about zero.[2] Second, for empirical reasons, East Beach and West Beach have been aggregated into one site. The basic reason for aggregation is the high correlation between the distance from any point in the greater New Bedford area to East Beach and the distance from the same point to West Beach. Exhibit 4 shows this correlation to be greater than .99. Such a high simple correlation would make estimation results highly imprecise. Further, as is evident from Exhibit 2, East and West Beach are similar enough in character to be considered perfect substitutes, making the aggregation quite acceptable conceptually. They are both quite urban, have parking lots, and are about one-half mile apart.

The demand for the i^{th} household for the j^{th} site is assumed to depend upon the cost of travelling the distance from the census tract center where the household resides to the j^{th} site, and the travel costs to several competing sites in the area. The following beaches were considered to be the choice set for the New Bedford area households:

Beach	Town
East Beach	New Bedford
West Beach	New Bedford
Fort Phoenix	Fairhaven
West Island	Fairhaven
Apponagansett	Dartmouth
Demarest Lloyd	Dartmouth

As mentioned above, East Beach and West Beach are aggregated into one site.

The substantial collinearity among regressors (see Exhibit 4) seriously exacerbates model selection. I have selected the following models for East/West Beach and for Fort Phoenix as the best models for the analysis:

East/West

$$x_{ij} = g_j(PEB_i, PFTP_i, PWI_i, PDL_i, \beta_j) + \varepsilon_{ij}$$

Fort Phoenix

$$x_{ij} = f_j(PEB_i, PFTP_i, \beta_j) + \varepsilon_{ij}$$

where x_{ij} = trips by household i to beach j,
PEB_i = East Beach cost,
$PFTP_i$ = Fort Phoenix cost,
PWI_i = West Island cost,
PDL_i = Demarest Lloyd cost, and
β_j = coefficients for beach j.

Models with income and other socioeconomic variables performed about the same as the models here, and typically such variables are not significant demand shifters. Each household's cost to the respective beach is calculated as the roundtrip distance from the center of the census tract to beach, valued at $.208 per mile plus the cost of time. The cost of time is based on a simple mean of the after-tax opportunity cost of time of the household's spouses. The opportunity cost of time depends on the individual's occupation as explained in Exhibit 5. The opportunity cost of time is converted to an after-tax basis by multiplying by one less the marginal tax rate, explained in Exhibit 6. This figure is converted to an after-tax opportunity cost per minute, and multiplied by the estimated number of minutes from the Census tract of the respondent to the beach of concern.[3] In addition, there is a parking fee of $3 at Fort Phoenix and Demarest Lloyd except for those with passes.

Exhibits 7 and 8 give the equations used in the damage calculations. Exhibit 7 gives the two equations for the "with PCB's" planned 1986 trips to the two beaches. These equations were estimated on the subset of respondents who responded that they had visited any beach in the New Bedford area during 1985. Of the sample of 545 who responded to the telephone survey, 386 or 70.8 percent responded "yes" to this question. Of those, there were a number of unuseable responses for planned trips for East/West and Fort Phoenix, resulting in the 359 observations for East/West and 367 for Fort Phoenix, for the estimation of the equations in Exhibit 7. The equations given there are typical for results from cross-sectional data.

They show that trips are influenced by own prices and other prices. The own price coefficients are in excess of twice their standard errors.

Exhibit 8 gives the equations estimated from the response to the *question 14: the demand for East/West and Fort Phoenix "without PCB's"*. These equations are estimated on a larger data set and hence use more observations. Question 14 is asked of all respondents who answer "yes" to the question about whether they believe the Harbor to be contaminated by PCB's (question 11) or who identify PCB's as a contaminant in question 10. Of the 538 households in the telephone survey, 421 or 78.2% either identified PCB's or responded "yes" to the question about whether the harbor is contaminated with PCB's. Of the 421 observations, several had unuseable variables for the trips "without PCB's", resulting in 410 observations for East/West and 412 for Fort Phoenix.. All of the estimated own price coefficients exceed twice their standard errors.

To calculate damages from the contamination by PCB's we look at the area under the demand curve for planned 1986 trips and compare it with the area under the demand curve for planned 1986 trips "without PCB's". It can be shown that the area under a linear demand curve is $x^2/(-2b)$ when x is the level of trip and b is the own price coefficient for the beach in question. Therefore the damages for beach j are[4]

$$d_j = x'^2_j/(-2b'_j) - x^{o2}_j/(-2b^o_j)$$

where the superscript prime (′) indicates trips and demand coefficients after PCB's are removed and the superscript ought (∘) indicates trips and demand coefficients for the 1986 activities planned with current levels of PCB's.

Per household damages are calculated using a weighted median estimate of trips, with and without PCB's (x^o_j and x'_j respectively). The median rather than the mean is used as measure of central tendency because the median reduces the influence of outliers. The medians are calculated only from the groups of households who believe that PCB's have contaminated the New Bedford Harbor and who plan to attend the particular beach under the given PCB circumstance. Those who believe the Harbor to be contaminated by PCB's must either 1: identify PCB's as a contaminant or 2: respond "yes" to the question of whether the Harbor is contaminated by PCB's. (See questions 10 and 11 of the instrument). Households who do not perceive that the Harbor is polluted with PCB's *ought not to be ascribed benefits from the removal of* PCB's. The weight is the proportion of the households knowing about PCB's who plan to attend the beach under the given PCB circumstances. Exhibit 9 gives the weights, medians, and the weighted medians for each beach and each PCB circumstance. Exhibit 10 gives the per household damages for each beach. The damage per household aware of PCB's is $1.28 for East/West and $2.80 for Fort Phoenix.

To expand the per household damages in Exhibit 10 to the population, we must deal with two issues. First, damages added across beaches may under or overestimate the aggregate damages to a household who attends both beaches. The appendix shows that there is no reason to argue strongly in either direction. Consequently, we take the sum of the per household damages at East/West and Fort Phoenix as the correct measure of damages to the household for removing PCB's from both beaches. Summing the damages in Exhibit 10 gives damages per household of $4.08.

The second issue is that the per household damage applies to those households who perceive PCB's. In 1986, 78.2 percent of households perceived PCB's. However, as perceptions change over time, gradually more people become aware of PCB's. Further, as we look back, fewer people were aware of PCB's. Exhibit 11 shows the proportion of the sample aware of PCB's each year from 1975 to 1986. This Exhibit is derived from responses to question 12, which asked the household in what year they became aware of PCB's. This exhibit shows that only 8.55% of the households were aware of PCB's in 1975.

The damages of PCB contamination per household should be expanded only to the proportion of households aware of PCB's, as given by Exhibit 11, between 1979 and 1986. However, it is reasonable to believe that the proportion aware of PCB's will continue to grow after 1986. This sort of growth phenomenon is modelled most plausibly with the logistics growth function. This function will allow us to predict how the proportion of the population aware of PCB's will grow in the future. Using the observations in Exhibit 11, I have estimated the following logistics growth function[5]

$$P_t = \{1 + \exp[2.85 - .358t]\}^{-1}$$

where P_t is the proportion of the households aware of PCB's and t is the number of years into the future from 1975. This equation will allow the future proportion of households aware of PCB's to be predicted.

Using the proportions in Exhibit 11 for the years 1979-1986, and the predicted proportions from the equation above for the years 1987-2085, we can determine the number of households in any year who are aware of PCB's. Assuming the number of households remains constant at the 1985 estimate of 51,498 for the New Bedford area, we can estimate the number of households aware of PCB's. The present discounted value of damages can be calculated in two steps:

1) annual damages = number of households aware of PCB's x damages/household
= P_t(51498)($4.08)
= P_t $210,112

2) present discounted value of damages
= sum of annual compounded damages, 1979-1985
plus sum of annual discounted damages, 1986-2085

$$= \sum_{t=1979}^{2085} (1 + r)^{1986-t} P_t \$210,112,$$

where r is the discount rate. With a discount rate of r = .03, the damages to beach use are $7.509 million, discounted to 1986.

II. DAMAGES TO RECREATIONAL FISHING

A. Framework

Saltwater angling is a popular activity throughout Buzzards Bay. Individuals fish both from the shore and from boats. Several charter fishing companies operate out of New Bedford and Apponagansett Harbors. Captain Leroy, Inc. is a charter fishing company that operates two boats on a regular daily schedule from Fairhaven, from April to October. Several other small companies have boats that leave from Davis and Tripp Marina in Dartmouth.

Anglers catch a wide variety of bottom-feeding and migratory species. From the shore, the catch may include various groundfish, such as flounders, tautog and scup. Charter parties travel out as far as Cuttyhunk and the Elizabeth Islands. They often pursue bluefish and stripers, along with a wide variety of groundfish.

Evidence about the impact of PCB's on recreational fishing comes from two sources: a telephone survey of households in the New Bedford area and conversations with about 15 local anglers. Both sources of evidence reveal that anglers typically are aware of the PCB problem. Conversations with local anglers revealed several types of behavioral response to the PCB problem:

- anglers fish less often:
- anglers fish further south, away from the contaminated waters of New Bedford harbor; and
- the fish caught are not eaten, but thrown back.

The phone survey of area households corroborated the anecdotal information provided by anglers. Exhibit 12 summarizes the results of the survey. Of the 421 households sampled, 18.5 percent responded that they fished in new Bedford waters in 1985. The responses to the questions about PCB's show that anglers are aware of and respond to PCB's. Sampled households having members who fished in 1985 were asked if the presence of PCB's influenced their angling activity. Forty percent said they fished less often, 63 percent stated that they avoided certain areas, 30 percent said they threw fish back, and 29 percent said they cooked and ate fewer fish.

The damages to recreational fishing by PCB contamination are calculated as the benefit of access to fishing in the area without contamination less the benefit with contamination. The behavior of a representative angler is pictured in Exhibit 13a. This angler, with demand curve c*ad, incurs costs of c per trip, takes x trips and enjoys a surplus of c*ca, what he would pay to fish in the area.

To measure the damages to recreational fishing, we divide the water into three fishing areas:

- outside New Bedford waters;
- inside New Bedford waters, contaminated by PCB's; and
- inside New Bedford wates, not contaminated by PCB's.

Suppose that within New Bedford, the two areas are identical, except for PCB's. That is, in New Bedford waters, the services of the marine environment in the absence of PCB contamination are sufficiently homogeneous to regard different fishing sites as good substitutes. Then, for purposes of benefit estimation we can conceive of two responses to PCB's:

- demand for fishing in New Bedford shifts backward as anglers fish in other areas, such as out on the Cape; and
- anglers avoid the contaminated waters in New Bedford by travelling farther to fish uncontaminated waters, still in the New Bedford area.

To calculate the damages of the first response, we need to estimate demand curves and calculate the change in the areas under demand curves. To calculate the damages of the second response, we can calculate the increased costs incurred by anglers who must travel further. Though they continue to fish in the Acushnet estuary, they incur higher travel and time costs as they move their activities away from contaminated areas.

The following analysis computes damages only for the anglers who continue making trips in the greater New Bedford waters at a higher cost. In Exhibit 13b, x_2 is the level of trips taken by the angler at the higher costs, c1*. Damages can be approximated by $x_2 \Delta c$ (or number of trips times change in costs). This measure of damages does not include losses incurred by anglers who shift to substitute activities.

B. Empirical Analysis

Damages can be computed from estimates of the aggregate number of trips taken at a higher cost and the mean increase in cost. The telephone survey provides evidence on the aggregate number of trips affected. From the telephone survey, 18.5 percent of respondents went recreational fishing in 1985. This figure is greater than the state-wide average of 11.2 percent in 1980 for Massachusetts and 13.9 percent in 1980 for Rhode Island, but New Bedford is closer to the water and would be expected to have a higher rate.[6]

From the survey a good estimate of the central tendency of trips per household is the weighted median. The weight is the proportion of the group of households aware of PCB's who fished in the area north of Ricketsons Point/Wilbur Point. Sixty-four households fished there out of 72 who were aware of PCB's, for a weight of .89. The median level of trips among those angling households was 12. The weighted median is .89 (12) or 10.67 trips per household.

A good estimate of the number of household angling trips affected by PCB contamination is

> number of households x angling participation rate x proportion of anglers adjusting trips x proportion of angling households aware of PCB's x trips per angling household.

For the New Bedford area, there are 51498 households in 1985. Exhibit 12 shows the angling participation rate to be .185, and the proportion of anglers adjusting trips to be .63. Of angling households, the proportion aware of PCB's is 72/78 or .92. From the weighted median trips of 10.67, we estimate the number of trips adjusted as

$$51498(.185)(.63)(.92)(10.67) = 58{,}919 \text{ trips}$$

The costs of continued angling activities are estimated to increase because anglers shift their fishing further south in Buzzards Bay. Fishing further south but still within the basic area can be achieved in several ways.

First, boats can be put in at the same place and travel further south. Second, boats can be put in further south in Dartmouth or Sconticut Neck. Third, anglers who fish from shore can drive further south.

To estimate the costs of moving angling activity, consider boating and fishing from shore. Boaters can avoid areas perceived to be more contaminated by traveling at least a mile (two miles round trip). This move will take them south of Fort Rodman, away from locations close to the hurricane barrier. For a typical bass boat, travelling about 15 miles per hour and using four gallons per hour, the fuel cost of moving one mile further south (two miles roundtrip) would be $.61 (at the mean 1985 price for self-service unleaded gas, $1.15 per gallon). Travelling the two miles would take about eight minutes. Valuing time at the Federal minimum wage of $3.35 would imply time costs of $.44. The sum is $1.05. Slower boats would be cheaper to operate but would impose higher time costs. For auto travel, suppose anglers can drive one and one-half more miles (or three miles roundtrip). Such an increase would allow anglers to fish areas on the east side of Sconticut Neck. The average cost of auto travel is $.208 per mile. Cars travel at about 40 miles per hour for extra miles. Then the three additional miles would impose a total cost of $.87 on an individual valuing his time at $3.35 per hour. When trips are equally divided between boats and shore, the average increase in costs is $.96 per trip.

The total damages any year are the product of the mean displacement costs and the aggregate number of trips affected:

$$\text{damages} = \Delta c \cdot \text{number of trips affected},$$

where Δc is the increase in costs.

Given these estimates, the losses incurred in any one year by recreational anglers are $56,562 ($.96 per trip times the number of annual trips (58,919) that are moved in response to the PCB contamination).

To conclude the angling analysis, the damages from 1979 to 1985 must be compounded to 1986 and the damages from 1987 to 2085 must be discounted to 1986. It is assumed that the same path of adjustment in awareness to PCB's among anglers occurs at the same rate as among the population in general. This simplification will slightly underestimate the damages to recreational fishing. The present value of damages to recreational fishing is

$$\sum_{t=1979}^{2085} (1 + r)^{1986-t} P_t \$56562 = \$2.02 \text{ million}$$

where r = .03 and P_t, the proportion of households aware of PCB's, is calculated from Exhibit 11 and the logistics growth function estimated from Exhibit 11.

This estimate of damages is conservative in that it ignores several behavioral changes, and calculates the cost of only one change: avoiding certain areas. It seems quite likely that higher costs are imposed on those who quit angling because of PCB contamination.

III. CONCLUSION: THE PRESENT VALUE OF DAMAGES TO RECREATIONAL ANGLING AND BEACH USE.

The present value of damages from PCB contamination to recreation activity in the New Bedford area is the sum of damages to recreational fishing and beach use. The present value of damages are

beach use	$7.51 million
recreational angling	$2.02 million
Total damages	$9.53 million

These damages are conservative in many respects, for example, in not covering activity changes at some beaches, in not counting as damaged any summer visitors, and in not dealing with a variety of averting actions in recreational fishing.

FOOTNOTES

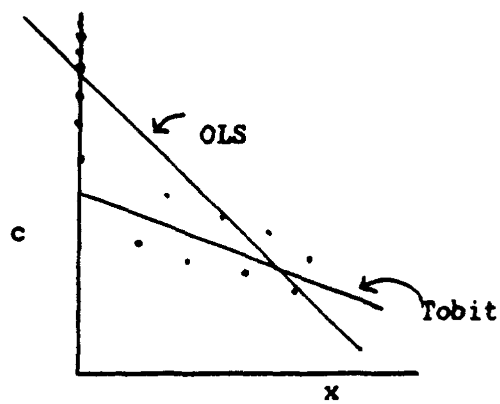
[1] The information on the survey was provided by Decision Research Corporation.

[2] The Tobit model is an approach to estimating functions which take only zero or positive numbers. For recreational applications, the model is

$$x = z\beta - \varepsilon \qquad z\beta - \varepsilon > 0$$
$$x = 0 \qquad z\beta - \varepsilon \leq 0$$

where ε is assumed normal with zero mean, constant variance. This model is explained in detail in Maddala, Ch. 6. It recognizes that when price (or other appropriate variable) gets high enough, quantity demanded goes to zero, and stays there. Estimating Tobit models rather than OLS usually results in more elastic recreational demand models. (See, for example, the results of Smith and Desvousges, 1985.)

The effect of using a Tobit estimation procedure which recognizes the nonnegative nature of recreational demand can be seen by looking at observations in price quantity space, all else equal.



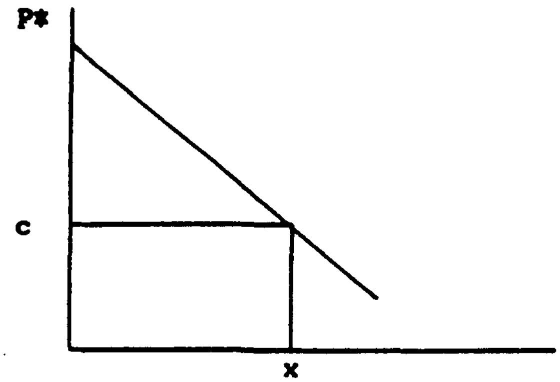
The OLS model will treat the zeroes and positive demands the same, and fit a function which minimizes squared deviations from a line drawn through all the points. The Tobit procedure fits a model which explains whether people take trips at all, and given that thay take these trips, what their demand curve is like. The graph shows that the OLS model estimates a slope too steep for participants, and will overestimate consumer's surplus for participants.

[3] The survey (question 6) sought from each respondent the estimated time to travel to the beach of concern. There were many non-responses to this question. Further the answers seemed highly variable. To reduce potential errors, and to provide estimates for those individuals who did not respond to the questions about time, I followed the following procedure. Time from the i^{th} Census tract to the j^{th} beach is the mean of all observations for that Census tract - beach combination if there are at least three respondents given their perceived time in that cell. If there are fewer than three respondents, time is estimated according to the following equation

$$t_{ij} = 6.95 + 1.49\ d_{ij}$$

where t_{ij} and d_{ij} are respectively time and distance from Census tract i to beach j. This equation was estimated from the pooled responses about the time to all sites (all responses to question 6).

[4]



This result is derived as follows: Let the i^{th} individual's demand curve be

$$x_i = \gamma_i + \beta c_i$$

where γ_i is the constant term and other arguments of the demand curve. A price of P* will reduce quantity demanded to zero:

$$0 = \gamma_i + \beta P_i^*$$

or
$$P_i^* = -\gamma_i/\beta$$

Consumer's surplus, the shaded triangle below the demand curve above the cost is

$$(P_i^* - c_i)x_i/2 = \left[\frac{-\gamma_i}{\beta} - c_i\right] x_i/2$$

$$= \left[\frac{-\gamma_i}{\beta} - \frac{x_i}{\beta} + \frac{\gamma_i}{\beta}\right] \frac{x_i}{2}$$

$$= -x_i^2/(2\beta)$$

where the second line follows from the fact that $x_i = \gamma_i + \beta c_i$ or $c_i = (x_i - \gamma_i)/\beta$

[5] The equation $P_t = (1 + \exp(2.85 - .358t))^{-1}$ is estimated from the data in Exhibit 11 by the following OLS equation

$$\mathrm{LOG}[P/(1-P)] = a + bt$$

where t = 1 for 1975, 2 for 1976 and so forth. The t-statistics for the estimated coefficients exceed 20 and the R^2 = .98.

[6] 1980 Survey of Hunting, Fishing and Wildlife-Associated Recreation, Table 10.

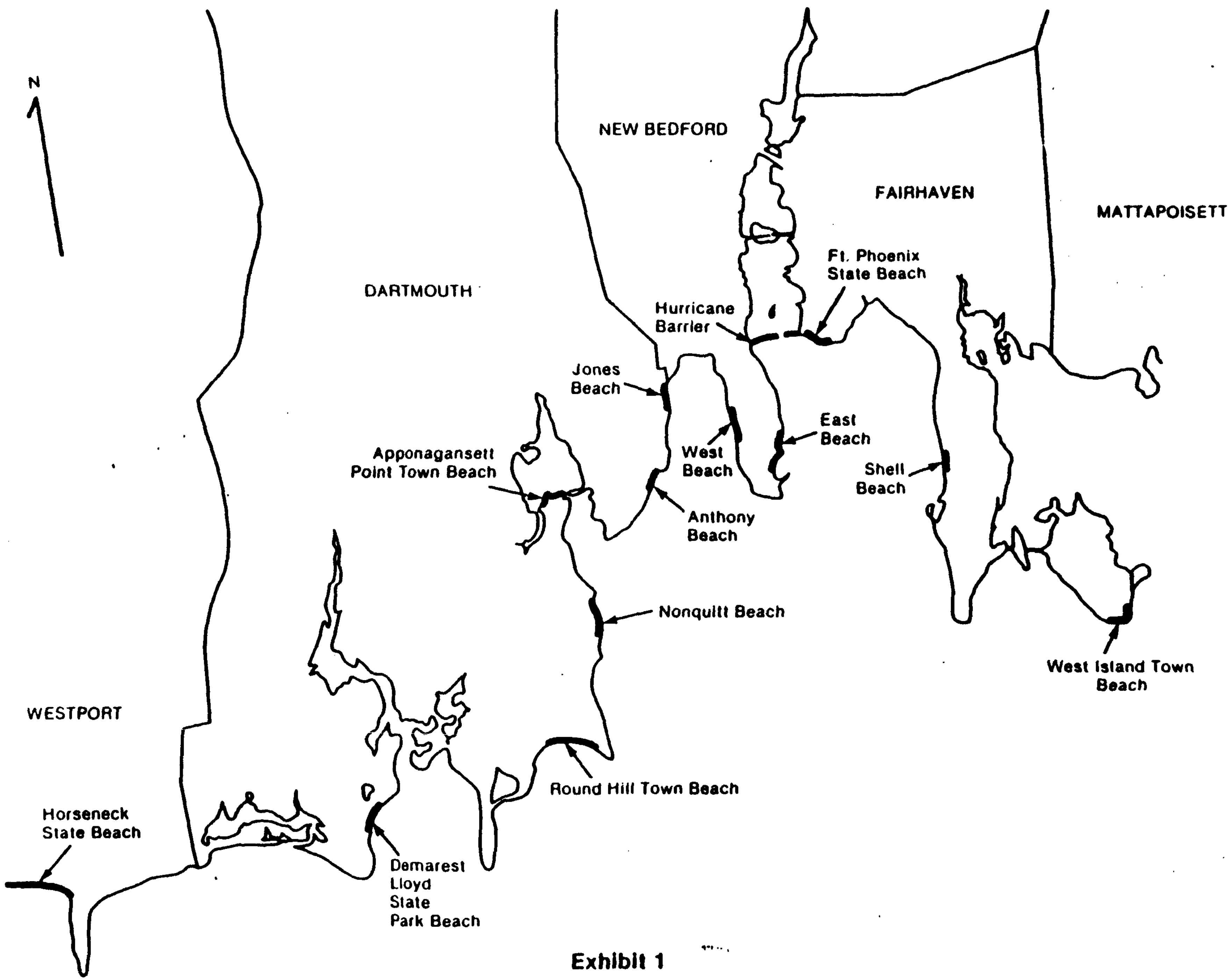


Exhibit 1

APPROXIMATE LOCATION OF BEACHES IN THE NEW BEDFORD AREA

Exhibit 2

SUMMARY OF CHARACTERISTICS OF BEACHES IN THE NEW BEDFORD AREA
Source: Christine Ruf, Industrial Economics, Inc.

Town/Beach	Jurisdiction	Attendance	Fee	Approximate Dimensions	Physical Characteristics	Other Characteristics
NEW BEDFORD						
East Town Beach	Town	'71-'85 (from cars)	No	.25 mi x 125 ft of beach	3 free pkg lts (200 cars); concession std.; swingset; lifeguard; bath & shower; cement pier (25' x 75')	Extremely urban; right next to busy road; visitor stratification by age on beach; can walk or take bus ($.30) 75% sand, 25% cobbles.
West Town Beach	Town	'71-'85 (from cars)	No	.5 mi x 100 ft of beach	Pkg along road (100 cars); bath house; concession std. across st.; long jetty at end of beach w/ boat ramp; lifeguard	Somewhat nicer than East Beach but still very urban; on a busy road; stratification by age; can walk or take bus, 75% sand, 25% cobbles.
FAIRHAVEN						
Fort Phoenix	State	'73-'85	$3 per vehicle per day; $20 per season.	21 acres 2,400 ft. bch	Bathouse; pkg lot (150 cars); concession; plygrd; grassy fld; tennis cts; basktbl court; lifeguard	Nice beach and view; lots of seaweed on shore; woods in back; big rock outcrops; quiet; 70% sand; 30% boulders/cobbles.
West Island	Town	900 - 1,100 car stickers per year	$5 per seasonal sticker; resid. & renters only	.75 mi x 500' beach; ~.5 mi x 50' dune	Dirt pkg lot (100 cars) 2-story lkout tower; lifeguard	Very nice & open; feeling of isolation (at end of ngbhd st) 75% sand; 25% boulders/cobbles.
Informal beaches: (along West Sconticut Neck, e.g. Shell Beach)	N/A	N/A	No	var. length; width from 20' to 75'	No facilities; limited access; occasional pkg. on nearby street	Beaches range from all sand to all cobble; lots of jetties.

Exhibit 2
(continued)

SUMMARY OF CHARACTERISTICS OF BEACHES IN THE NEW BEDFORD AREA

Town/Beach	Jurisdiction	Attendance	Fee	Approximate Dimensions	Physical Characteristics	Other Characteristics
DARTMOUTH						
Demarest Lloyd State Park	State	'73-'83 (based on cars)	$3/day, $20/season, per vehicle	220 acres; 1,800 lin. ft. beach	Bathhouse; lfgd; picnic area; 2 pkg lots (450 cars)	Shallow water; nice beaches; good for birding; salt marshes
Round Hill	Town	Based on no. of stickers only	$5 seasonal sticker, resident only	1 mi x 75 ft	Pkg for 250-300 cars; picnic area; lfgds	N/A
Jones Beach	Town	Based on no. of stickers only	$5 seasonal stk. residents, $5/day/vehicle non-resident	.33 mi x 100 ft	Pkg for 150 cars picnic area	Small waves; This is known as a small children's beach.
Apponagansett Pt.	Town	Based on no. of stickers only	$5 seasonal stk. residents, $5/day/vehicle non-resident	.5 mi x 100 ft	Picnic area; parking for 100 cars; lifeguard; boat ramp	Rocky beach; little sand; good for shellfishing.
Anthony Beach	N/A	N/A	Must be club member	N/A	N/A	N/A
Nonquitt Beach	N/A	N/A	N/A	N/A	N/A	N/A
WESTPORT						
Horseneck Beach	State	'75-'85 (based on cars)	$3/day; or $20/season, per vehicle	594 acres; 10,000 ln ft of beach	Pkg for 2,000 cars, lifeguard; boat ramp; 100 campsites	Barrier dunes; salt marshes; nice surf; great view.

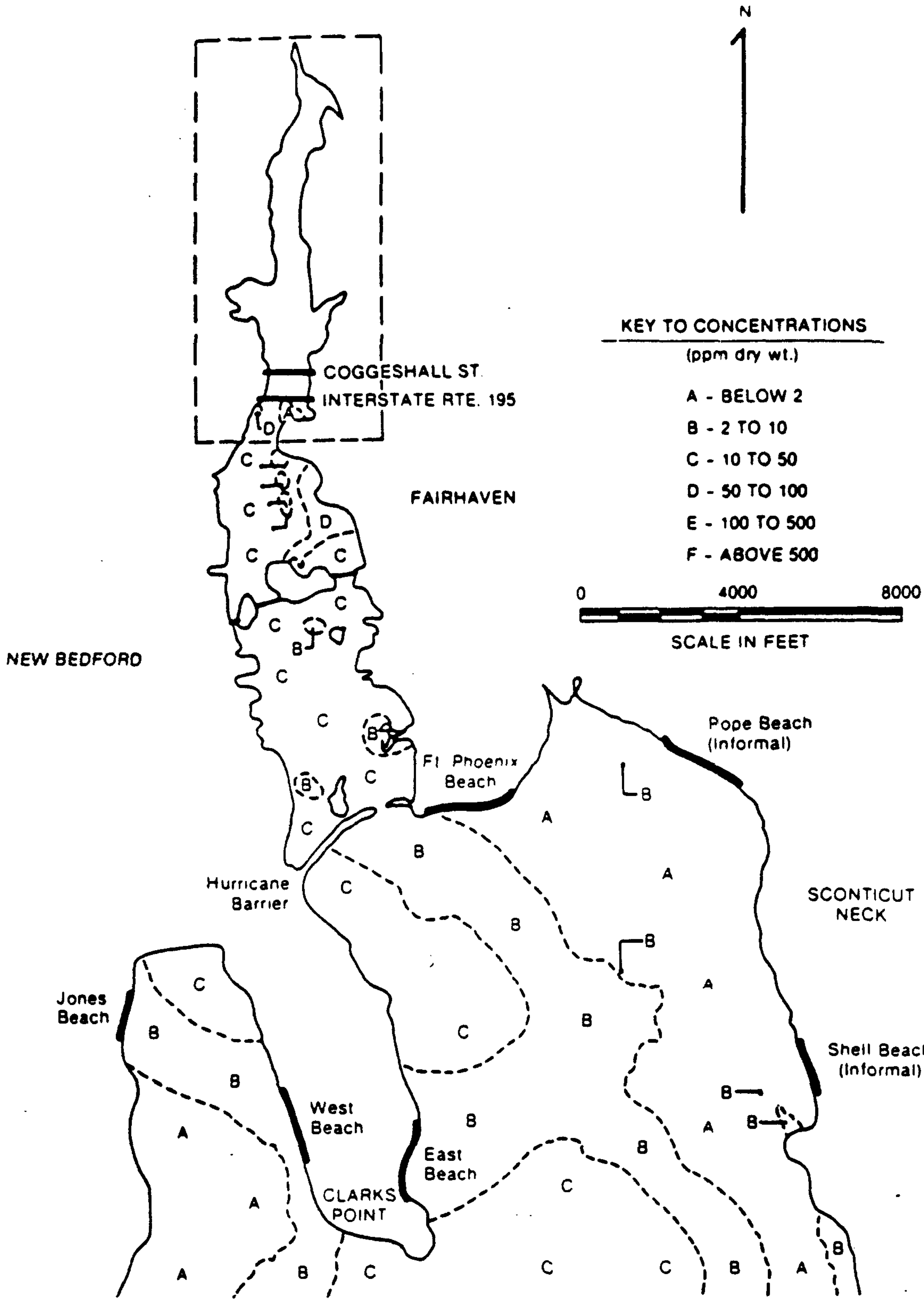


Exhibit 3

SEDIMENT CONCENTRATIONS, ACUSHNET RIVER ESTUARY NEW BEDFORD, MASSACHUSETTS

Source: NUS Corporation, July 1984

Exhibit 4

SOME SIMPLE CORRELATION COEFFICIENTS AMONG DISTANCES FROM CENSUS TRACTS TO BEACHES[a]

East Beach	-					
West Beach	.999	-				
Fort Phoenix	.625	.658	-			
West Island	.332	.284	.873	-		
Demarest Lloyd	.127	.185	-.498	-.625	-	
Apponagansett	.590	.562	-.081	-.270	.868	-

[a] The correlation coefficients are calculated across all observations.

Exhibit 5

PRE-TAX OPPORTUNITY COST OF TIME

Questionnaire occupation	Employment and Earnings source	Hourly rate
Salaried employee[a]	weighted average of (1) Executive, administrative and managerial and (2) technical, sales and administration support. Weights are numbers of workers in each group	$8.86
Self-employed	unweighted mean of major occupation groups	7.84
Professional	professional specialty	11.90
Tradesmen	precision production, craft and repair	9.68
Executive	executive, administration and managerial	12.33
Services	service occupations	5.33
Hourly worker	handlers, equipment cleaners, helpers and laborers	6.45
Education	technical sales and administrative	7.50
Homemaker, never worked, other, refused	minimum wage	3.35

[a] The opportunity cost of time for each occupation of the questionnaire is based on median earnings according to the categories listed for the occupation. The hourly rates are computed as median weekly earnings divided by 40 hours for the fourth quarter of 1984, as given in Employment and Earnings, Vol. 33, No. 1, January, 1986, Table A-75. The categories Homemaker, never worked, other and refused are assigned the Federal minimum wage.

Exhibit 6

MARGINAL TAX RATES[a]

Income Category	Marginal Tax Rate
Under $15,000	.192
$15,000 to $19,999	.229
$20,000 to $24,999	.264
$25,000 to $34,999	.315
$35,000 to $49,999	.385
$50,000 and over	.454
not reported	.229

[a] These rates are the average marginal rates that would be paid by a married couple, filing jointly with income in the given range, in 1985. The rates include the Massachusetts income tax of .05375.

[b] A household receives one less the marginal tax rate of each dollar earned. A person in a household with reported income less than $15,000 would receive almost 80% (1 - .192) of each dollar earned.

Exhibit 7

DEMAND COEFFICIENTS FOR PLANNED 1986 TRIPS:
WITH PCB's.[a]

Variables	Constant	PEB	PFTP	PWI	PDL	Log likelihood	Number of observations
East/West	-31.5 (1.4)	-9.1 (3.6)	-2.7 (1.1)	2.9 (1.4)	3.5 (2.1)	-830.3	359
Fort Phoenix	2.68 (.5)	3.5 (3.1)	-4.0 (4.8)	-	-	-683	367

[a] Estimated with the University of Maryland SHAZAM package.

[b] Parentheses contain asymptotic t-statistics under null hypothesis of no association.

Exhibit 8

DEMAND COEFFICIENTS FOR 1986 TRIPS: WITHOUT PCB's.[a]

Variables	Constant	PEB	PFTP	PWI	PDL	Log likelihood	Number of observations
East/West	-32.0 (1.3)	-13.2 (4.6)	-4.5 (1.7)	5.6 (2.5)	4.5 (2.4)	-1216.2	410
Fort Phoenix	15.8 (3.2)	2.1 (2.0)	-3.6 (4.6)	-	-	-1130.1	412

[a] Estimated with the University of Maryland SHAZAM package.

[b] Parentheses contain asymptotic t-statistics under null hypothesis of no association.

Exhibit 9

CAI ^ULATION OF ESTIMATED PER HOUSEHOLD TRIPS

	Proportion of Households Knowing About PCB's Who Attend	
	East/West Beach	Fort Phoenix
1986 with PCB's	.452	.361
1986 without PCB's	.531	.534

	Median Trips per Household Among Households Who Plan to Attend The Particular Beach and Who Know About PCB's.	
	East/West Beach	Fort Phoenix
1986 with PCB's	10	5
1986 without PCB's	15	9

	Weighted Median Trips	
	East/West Beach	Fort Phoenix
1986 with PCB's	4.52	1.81
1986 without PCB's	7.97	4.81

Exhibit 10

ESTIMATED PER HOUSEHOLD DAMAGES

East/West Beach	Fort Phoenix
$1.28	$2.80

Exhibit 11

PROPORTION OF SAMPLE HOUSEHOLDS AWARE OF PCB's, BY YEAR

Year[a]	Proportion Aware of PCB's
1975	.0855
1976	.130
1977	.143
1978	.176
1979	.207
1980	.299
1981	.397
1982	.493
1983	.605
1984	.737
1985	.775
1986	.782

[a] Based on question 12 which asked when the household became aware of PCB's.

Exhibit 12

RESPONSES TO RECREATIONAL FISHING QUESTIONS
(PERCENT OF RESPONDENTS ANSWERING YES)

Fished in 1985	18.5% (78 of 421)
Changed fishing Habits Because of PCB's:[a]	
Fish Less Often	40%
Avoid Certain Areas	63%
Throw Fish Back	38%
Cook and Eat Less Fish	29%

[a] Of the 78 respondents who fished in 1985

Exhibit 13a

DEMAND FOR RECREATIONAL ANGLING

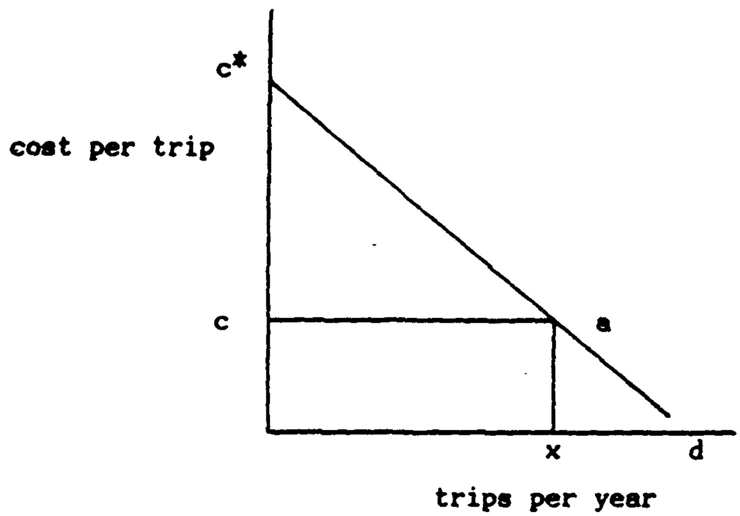
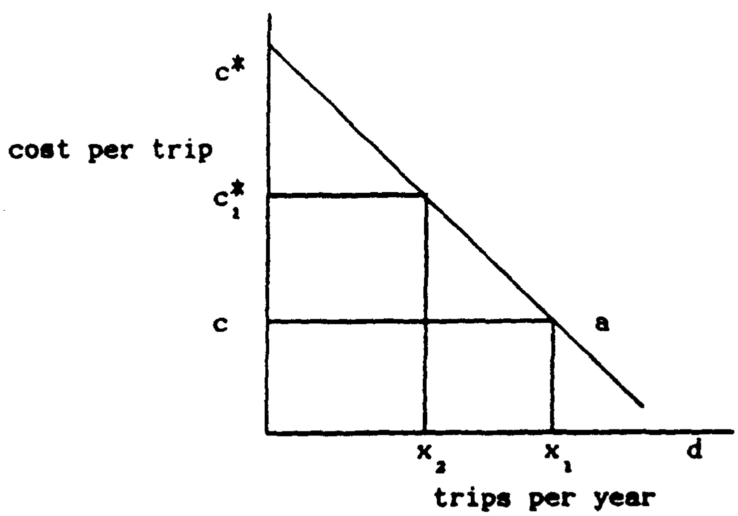


Exhibit 13b

CONSUMER SURPLUS LOSS DUE TO INCREASED COST OF RECREATIONAL ANGLING



APPENDIX

Further Development of Concepts

1. Basic Measures.

Consider the m beach problem where visits to the m beaches are the first m components of the ($m < n$) n-dimensional vector x, the consumer's choice vector. Utility is given by $U = U(x,\alpha)$ where α_i is the exogenous quality index of site i, $i = 1,\ldots,m$. While α_i will have only one dimension, it is a simple bookkeeping problem to extend the analysis to several dimensions. Further, weak complementarity is assumed, so that when there are no visits to the i^{th} beach, the consumer is indifferent to quality at the i^{th} beach. (See Freeman: The Benefits of Environmental Improvements.) The problem is to calculate the benefits of changing the quality at some subset of the m sites; for convenience I analyze the case where quality changes at two of the m sites. In effect, I calculate the benefits (or costs) of changing the parameter vector from $(\alpha_1^0,\alpha_2^0,\bar{\alpha})$ to $(\alpha_1^1,\alpha_2^1,\bar{\alpha})$ where $\bar{\alpha} = (\alpha_3^0,\ldots,\alpha_m^0)$. That is, the first two components of the quality vector change, leaving the last m-2 in their original state. Benefits or damages are derived from the expenditure function, which is defined by

$$C(p^o,\alpha) = \max\{xp^o \mid U(x,\alpha) = U\} \tag{1}$$

where p^o is the vector of prices paid for x, and U is reference utility level, which is suppressed as an argument in $C(p,\alpha)$.

For people who visit both beaches, the benefits of a change in several components of α are given by

$$b = -\left[C(p^o,\alpha^1) - C(p^o,\alpha^o)\right] \tag{2}$$

where $\alpha^i = (\alpha_1^i,\alpha_2^i,\bar{\alpha})$, $i = 1,2$. The issue here is to show that the basic definition of benefit change, given by equation (2), can be estimated as areas under demand curves of sites 1 and 2 only. Expression (2) can be identically rewritten as

$$b = -[C(p^o,\alpha^1) - C(p^o,\alpha_1^0,\alpha_2^1,\bar{\alpha}) + C(p^o,\alpha_1^0,\alpha_2^1,\bar{\alpha}) - C(p^o,\alpha^o)] \tag{3}$$

by adding and subtracting $C(p^o,\alpha_1^0,\alpha_2^1,\bar{\alpha})$. Using the notation for Hicksian demand curves $\partial C/\partial p_i = h_i(p,\alpha)$, and assuming weak complementarity between α_i and site i, we can write this as

$$b = \int_{p_1^0}^{p_1^*} h_1(p_1,p_2^0,\alpha_1^1,\alpha_2^1,\bar{\alpha})dp_1 - \int_{p_1^0}^{p_1^{**}} h_1(p_1,p_2^0,\alpha_1^0,\alpha_2^1,\bar{\alpha})dp_1$$

$$+ \int_{p_2^0}^{p_2^*} h_2(p_1^0,p_2,\alpha_1^0,\alpha_2^1,\bar{\alpha})dp_2 - \int_{p_2^0}^{p_2^{**}} h_2(p_1^0,p_2,\alpha_1^0,\alpha_2^0,\bar{\alpha})dp_2 \tag{4}$$

where p_1^*, p_1^{**}, p_2^*, and p_2^{**} are the choke prices for sites 1 and 2 respectively.[1] The choke prices depend on the quality vector and price vector, and therefore differ for the same site as demand curves shift. The functional dependence of p^* on α and p^o is implicit in what follows, but does not influence the construction. The result (4) is critical to welfare measurement. It states that the welfare effects of changes in the quality of several sites can be calculated as the sum of the areas under the appropriately located Hicksian demand curves for site one and site two. Expression (4) follows from (3) in two steps. First, the integral on the first line of (4) is

$$\int_{p_1^o}^{p_1^*} [h_1(p_1,p_2^o,\alpha_1^1,\alpha_2^1,\bar{\alpha})dp_1 - \int_{p_1^o}^{p_1^{**}} h_1(p_1,p_2^o,\alpha_1^o,\alpha_2^1,\bar{\alpha})]dp_1$$

$$= C(p_1^*,p_2^o,\alpha_1^1,\alpha_2^1,\bar{\alpha}) - C(p^o,\alpha_1^1,\alpha_2^1,\bar{\alpha}) - \left\{C(p_1^{**},p_2^o,\alpha_1^o,\alpha_2^1,\bar{\alpha}) - C(p^o,\alpha_1^o,\alpha_2^1,\bar{\alpha})\right\}$$

$$= - [C(p^o,\alpha^1) - C(p^o,\alpha_1^o,\alpha_2^1,\bar{\alpha})] \tag{5}$$

$$\text{because } C(p_1^*,p_2^o,\alpha_1^1,\alpha_2^1,\bar{\alpha}) = C(p_1^{**},p_2^o,\alpha_1^o,\alpha_2^1,\bar{\alpha})$$

where the last equality holds by weak complementarity. That is, the cost function is not responsive to changes in α_1 when $x_1 = 0$ (or p_1 is so high that $x_1 = 0$). Hence the first two terms on the right hand side of (4) are equal to the first two terms on the right hand side of (3). A similar analysis shows that the second two terms on the right hand side of (3) equal the second two terms on the right hand side of (4).

This expression tells us that we can compute an individual's total benefits of quality changes at several sites by adding up changes in areas under Hicksian demand curves, as long as the demand curves have the appropriate quality arguments. Specifically benefits at site 1 are computed assuming α_2^1 (new quality at site 2), while benefits at site 2 are computed assuming α_1^o (old quality at site 1).

This result is a substantial help in calculating benefits. Intuitively, changes in the quality at one site influence an individual's use of other sites, and even purchases of non-recreational goods. The result in (4) states that we do not need to keep track of all the changes in behavior that are induced by a quality change at the i^{th} site. In fact, all we have to do is to find out how the demand curve at the i^{th} site shifts. This result is analogous to welfare measurement of multiple price changes, which is done by sequentially calculating the areas under the demand curves for the goods whose prices change. (See Just, Hueth and Schmitz.)

2. Aggregation Problems

In the New Bedford case, the nature of the situation makes it difficult to measure the sequencing properly. Discovery and public awareness of PCB contamination occurred over a short period of time. Hence we can observe

$(\alpha_1{}^0,\alpha_2{}^0)$, and hypothetically construct $(\alpha_1{}^1,\alpha_2{}^1)$ but consider it impossible to observe or construct hypothetically $(\alpha_1{}^0,\alpha_1{}^1)$ or $(\alpha_1{}^1,\alpha_2{}^0)$ (one beach clean, the other polluted). Consequently, we observe and hypothetically construct the following measure of benefits, aggregated across sites (when the α argument is assumed implicit):

$$b^o = \int_{p_1^o}^{p_1^*} [h_1(p_1,p_2^o,\alpha_1^1,\alpha_2^1) - h_1(p_1,p_2^o,\alpha_1^o,\alpha_2^o)dp_1$$

$$+ \int_{p_2^o}^{p_2^*} [h_2(p_1^o,p_2,\alpha_1^1,\alpha_2^1) - h_2(p_1^o,p_2,\alpha_1^o,\alpha_2^o)]dp_2 \qquad (6)$$

when it is assumed *for simplicity that* $p_1^* = p_1^{**}$, *without influencing the result.* Let b be the correct measure of damages with the appropriate sequencing of the quality variables, b^o the measured damage and a to be defined below. Since b^o is the measured damage, b the true damages, we look for the difference between b and b^o. Through tedious manipulations and repeated application of weak complementarity to (6), it can be shown that

$$b^o = b - (a - b) \qquad (7)$$

where a is a measure of benefits such as b^o above, but with the p_1^o in $h_2(p_1^o,\ldots)$ and p_2^o in $h_1(.\ p_2^o..)$ replaced by p_1^* and p_2^*. Hence a is positive, and may exceed b^2. We see that b^o (observed benefits) differs from b, true benefits given in equation (4), all errors of estimation aside, as follows:

$$b^o - b = b - a \qquad (8)$$

We can express a as an unknown constant times b:

$$a = kb.$$

Then we can write b^o as

$$b^o = (2 - k)b$$

If k is less than 1, b^o overestimates b; if k is greater than 1, b^o underestimates b. *There are no strong empirical* or *conceptual reasons* to suppose that k is greater or less than one. (In fact, minimal conceptual work suggests that k > 1.) Without evidence, the most judicious approach is to assume that k = 1, so that b^o - b (measurement errors aside).

3. The Hicksian vs. Marshallian issue

The discussion so far has been developed only in terms of Hicksian demand curves, whereas we observe behavior derived in principle, at least, from Marshallian demand curves. The differences between Hicksian and Marshallian measures of welfare for price changes have been explored in painful detail. The differences in the welfare effects of quality changes have not been similarly explored. For the case of interior solutions, there is no reason to anticipate any uncommon differences between the more correct measures of equivalent or compensating variations and the more easily calculated consumer's surplus measure.

One can see that strong income effects create the potential for disparities. The Hicksian demand for a site can be written

$$x_i = h_i(p,\alpha,u)$$

while the observed Marshallian is

$$x_i = f_i(p,\alpha,y).$$

The Hicksian and Marshallian are equal at the point where income equals the minimum expenditures needed to reach u or where $y = C(p,\alpha,u)$:

$$h_i(p,\alpha,u) = f_i(p,\alpha,C(p,\alpha,u))$$

Differentiating with respect to both sides gives

$$\frac{\partial h_i}{\partial \alpha} = \frac{\partial f_i}{\partial \alpha} + \frac{\partial x_i}{\partial y}\,\frac{\partial C}{\partial \alpha}\,.$$

This expression tells us that the response of the Hicksian and Marshallian demand function differ by $(\partial x_i/\partial y)\cdot(\partial C/\partial \alpha)$, the income effect times the change in minimum cost with respect to quality. The difference between equivalent or compensating variation and consumer's surplus also depends computationally on the limit prices. But we can see that if the income effect is small, then the Hicksian and Marshallian functions will respond the same to quality changes and it is reasonable to assume that the surplus and the variations will be close. If the income effect is large, then one would have grounds for arguing that there are substantial differences. It seems quite plausible to argue that consumer's surplus is a good measure of either the willingness to pay for beach access or the amount beach users would have to be paid to relinquish access.

4. Introducing Additional Sites

What if more than two beaches are affected? Can we tell the direction of bias if the environmental quality at other beaches is influenced (as it almost surely is)? We can address this question by looking at the costs of quality changes at n sites, and seeing what happens if we measure welfare changes at less than n. Suppose that α changes from α^0 to α^1. Then the benefits (if an improvement) of this change are

$$b = -\,[C(p,\alpha^1) - C(p,\alpha^0)]$$

This can be written

$$b = -\ [C(p,\alpha^1) - C(p,\alpha_1^1,\ldots,\alpha_{n-1}^1,\alpha_n^0)$$

$$+ C(p,\alpha_1^1,\ldots,\alpha_{n-1}^1,\alpha_n^0) - C(p,\alpha_1^1,\ldots,\alpha_{n-2}^1,\alpha_{n-1}^0,\alpha_n^0)$$

$$+ C(p,\alpha_1^1,\ldots,\alpha_{n-2}^1,\alpha_{n-1}^0,\alpha_n^0) - C(p,\alpha_1^1,\ldots,\alpha_{n-3}^1,\alpha_{n-2}^0,\alpha_{n-1}^0,\alpha_n^0)$$

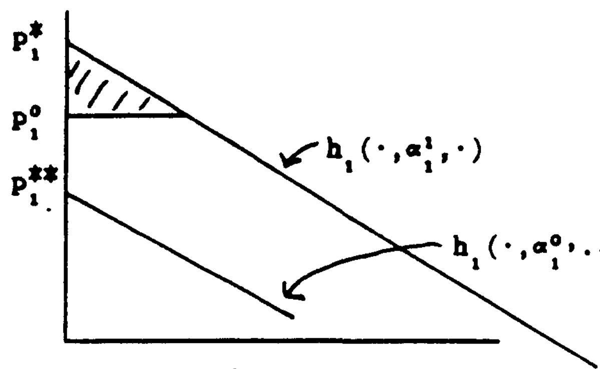
$$+ \quad \vdots$$

$$C(p,\alpha_1^1,\alpha_2^0,\ldots,\alpha_n^0) - C(p,\alpha^0)].$$

If all of the α's increase (i.e., there is an improvement everywhere) then it is reasonable to assume that each Hicksian demand curve shifts out as a result of its own improvement in quality. Hence, measuring the quality improvements at some sites underestimates the benefits of the improvement. Whether Hicksian demand curves shift out as a result of quality improvements is an empi: cal question whose answer depends on the strength of the income effect.

FOOTNOTES TO APPENDIX

1 This expression also holds if a person initially visits only one site or no sites. That is, $p_1^o \geq p_1^{**}$, or $p^o \geq p^{**}$. Here the argument is made for the case where $p_1^o \geq p_1^{**}$. In that case, the integral $\int_{p_1^o}^{p_1^{**}} h_1(p_1,\cdot)\,dp_1$ must be identically zero, because quantity demanded is initially zero and cannot change as price increases. Hence benefits for x_1 are simply $\int_{p_1^o}^{p_1^*} h_1(p_1,\cdot)dp_1$ or the shaded area in the figure below.



The same reasoning holds for x_2 or for both sites jointly.

2 Expression (7) can be demonstrated as follows:
Writing out b^o from (6), we have

$$b^o = \left\{ \int_{p_2^o}^{p_2^*} [h_2(p_1^o,p_2,\alpha_1^1,\alpha_2^1) - h_2(p_1^o,p_2,\alpha_1^o,\alpha_2^o)]dp_2 \right.$$

$$\left. + \int_{p_1^o}^{p_1^*} [h_1(p_1,p_2^o,\alpha_1^1,\alpha_2^1) - h_1(p_1,p_2^o,\alpha_1^o,\alpha_2^o)]dp_1 \right\}$$

By integrating this expression for b^o, we have

$$\begin{aligned} b^o = \Big\{ & C(p_1^o,p_2^*,\alpha^1) - C(p^o,\alpha^1) \\ & - C(p_1^o,p_2^*,\alpha^o) + C(p^o,\alpha^o) \\ & + C(p_1^*,p_2^o,\alpha^1) - C(p^o,\alpha^1) \\ & - C(p_1^*,p_2^o,\alpha^o) + C(p^o,\alpha^o) \Big\} \end{aligned}$$

The second and fourth terms are b (see expression (2)), so b° is

$$b^{\circ} = b + \Big\{C(p_1^{\circ},p_2^{*},\alpha^{1}) - C(p_1^{\circ},p_2^{*},\alpha^{\circ}) - C(p^{\circ},\alpha^{1})$$

$$+ \; C(p_1^{*},p_2^{\circ},\alpha^{1}) - C(p_1^{*},p_2^{\circ},\alpha^{\circ}) + C(p^{\circ},\alpha^{\circ})\Big\}$$

$$= b + \Big\{C(p_1^{\circ},p_2^{*},\alpha^{1}) - C(p_1^{\circ},p_2^{*},\alpha^{\circ})$$

$$+ C(p_1^{*},p_2^{\circ},\alpha^{1}) - C(p_1^{*},p_2^{\circ},\alpha^{1}) + b\Big\}$$

$$= b - \{a - b\}$$

where $a = -\Big\{C(p_1^{\circ},p_2^{*},\alpha^{1}) - C(p_1^{\circ},p_2^{*},\alpha^{\circ})$

$$+ \; C(p_1^{*},p_2^{\circ},\alpha^{1}) - C(p_1^{*},p_2^{\circ},\alpha^{\circ})\Big\}.$$

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